

BERMUDASIGNUM FRANKENBERGI N. GEN., N. SP.
(CRUSTACEA: ISOPODA) OFF BERMUDA AND EVOLUTION
WITHIN THE DEEP-SEA FAMILY MESOSIGNIDAE

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ABSTRACT

The deep-sea asellote isopod family Mesosignidae, found primarily in the tropical latitudes in the east Pacific Ocean and the Caribbean Sea, is revised and several hypotheses are postulated to explain the evolution of species within this family. The emergence of the Isthmus of Panama is discussed as a driving force for allopatric speciation. The following four new genera *Bermudasignum*, *Costasignum*, *Japanosignum*, and *Kurilosignum* are diagnosed, a new deep-sea species from Bermuda Pedestal, *Bermudasignum frankenbergi* n. gen., n. sp. is described and its origin is explained as the most recent evolutionary event in the recent history of the family Mesosignidae.

This study is an evaluation of the morphological affinity of a new species of the deep-sea asellote isopod family Mesosignidae, collected by the author from the western side of the Bermuda Pedestal at 1390–1840 m during a cruise of the Duke University R/V EASTWARD cruise 1968. The results of this study suggested the need for revision of the family Mesosignidae Menzies and George, 1972, which contained species of diverse morphology, possibly belonging to different genera. A new genus is established in this paper to include this species *Bermudasignum frankenbergi* n. gen., n. sp. and three other species from the genus *Mesosignum* Menzies, 1962 are found to belong to this new genus. The following three genera are also diagnosed: *Costasignum* n. gen.; *Kurilosignum* n. gen.; and *Japanosignum* n. gen. A key to the genera of the family Mesosignidae is presented.

The depth and geographical distribution of all known species of the two genera *Mesosignum* and *Bermudasignum* are recorded. Three hypotheses are postulated to explain the possible origin of the family in the tropical central Pacific Ocean prior to the formation of the Isthmus of Panama about 3.5 million years ago, possible allopatric speciation of isolated populations of the parental Pacific species to a new Caribbean species, and speciation in the northwestern Atlantic Ocean leading to the formation of a new deep-sea species in the vicinity of the island of Bermuda.

Family Mesosignidae Menzies and George, 1972

Diagnosis.—Pereonites 2–6 with conspicuous lateral extensions. Cephalon mostly subquadrate with rounded fronts. First pereonite always the shortest in the pereon, without any lateral extension. Pereonites 2–6 with lateral margin significantly produced. Seventh pereonite with or without lateral extensions. Pleotelson produced slightly or prominently at the posterolateral angles, with or without lateral extensions. Antennule with seven or more articles in the flagellum. All seven pereopods are ambulatory, without any expansion of carpus or propodus and lacking natatory plumose setae. Uropod 2-jointed and uniramous, ventrolaterally inserted.

Remarks.—Birstein (1963) placed the genus *Mesosignum* in the family Munnidae, but he included this genus in a separate subfamily Pleurogoninae. Menzies and George (1972)

considered Mesosignidae as a separate family and described a new species, *M. truncatum*, at 4925 m in the Peru-Chile Trench. Kussakin (1988) also recognized Mesosignidae as a separate family within the superfamily Mesosignidae. *Mesosignum* is the only genus assigned to this family. Thus far, fourteen species are assigned to the genus *Mesosignum*, which is known mostly from the equatorial Pacific and Atlantic-Caribbean latitudes, except for two species in the trenches of the northwest Pacific Ocean (Birstein, 1963). In this study, this genus is redefined and four new genera are established. A simple key is developed to differentiate these genera.

Mesosignum Menzies, 1962

(Fig. 1)

Type Species.—*Mesosignum kohleri* Menzies, 1962.

Diagnosis.—Mesosignidae with pleotelson lacking any lateral extension, but with a prominent sharp or blunt posterolateral angle. Seventh pereonite devoid of any lateral extension. Cephalon invariably subquadrate in shape, with or without lateral or dorsal tubercles or setae.

Remarks.—This genus includes possibly seven known species, but only five are described (Fig. 1). Menzies and Frankenberg (1968) described *M. usheri* with three distinct varieties occupying a wide geographic range from the Caribbean to the east Pacific off Costa Rica, Chile, and Patagonia, ranging from 10–56°S in latitude. In this study, *M. usheri* is recognized as a distinct species (= Variety C) and Variety A and B are considered two undescribed species. Two character-states clearly distinguish *M. usheri* from Varieties A and B. These are (A) the presence of minute tubercles on the entire dorsal surface of the body that Variety A and B lack and (B) the larger seventh pereonite with, or more lateral spines. Nevertheless, Menzies and Frankenberg (1968) merely list these two varieties as Species A and B and it is not clear whether or not these two Varieties are genuine species.

1. *Mesosignum kohleri* Menzies, 1962 (the type species) from the Colombia continental rise to the Colombia abyssal plain, Caribbean Sea, 2868–4976 m. This species is so far known from two different deep-sea areas: 14°05'N, 75°25'W (4071–4076 m), Colombia abyssal plain and 11°30'N, 75°50'W (2868–2941 m), Colombia continental rise.

2. *Mesosignum usheri* Menzies, 1962 (Variety C) from 1016–1892 m off Ecuador Equatorial East Pacific Ocean. 06°21'N, 85°17'W.

3. *Mesosignum* Sp. A is known from the Caribbean Sea from 1533–1615 m off Panama at 10°11'N, 78°30'W; off Chile at 3147–3255 m and also from 4065 m off Chile at 35°47'S, 76°22'W.

4. *Mesosignum* Sp. B is known from the southern most range of this genus off Patagonia from 1805–2012 m at 56°04.5'S, 71°09.1'W.

5. *Mesosignum asperum* Menzies and Frankenberg, 1968 from the deep-sea off Costa Rica, 3528–3718 m at 10°07'N, 89°50'W; off Costa Rica, 3517–3528 m at 09°22'N, 89°33'W and off Nicaragua at 3950 m, 12°45'N, 88°38'W, all three records from the equatorial eastern Pacific Ocean.

6. *Mesosignum ansatum* Menzies and Frankenberg, 1968 from 3777–3950 m off Nicaragua, equatorial Pacific Ocean at 12°45'N, 88°38'W.

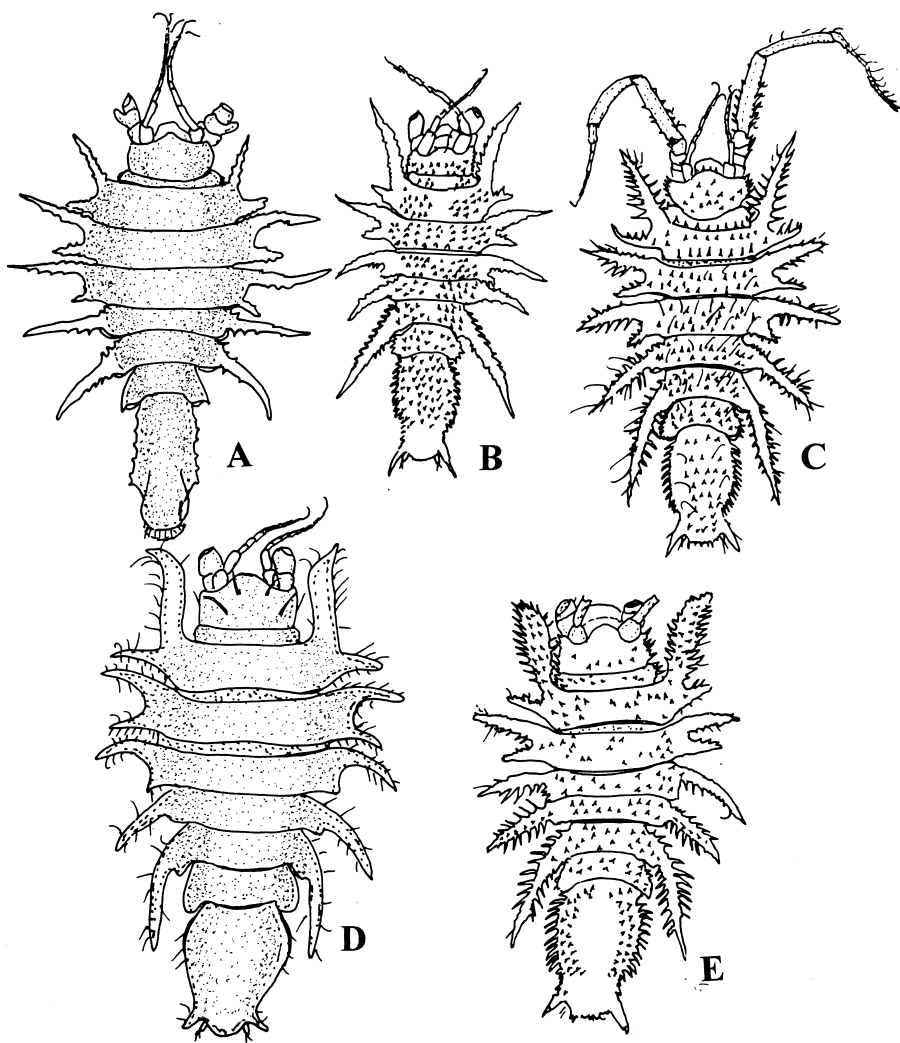


Figure 1. Species belonging to the genus *Mesosignum*, Menzies, 1962: A) Type species *Mesosignum kohleri* Menzies, 1962 B) *Mesosignum usheri* menzies, 1962 C) *Mesosignum truncatum* Menzies and George, 1972 D) *Mesosignum ansatum* Menzies and Frankenberg, 1968 E) *Mesosignum asperum* Menzies and Frankenberg, 1968

7. *Mesosignum truncatum* Menzies and George, 1972. From 4823–4925 m in the Peru-Chile Trench, the southeast Pacific Ocean at 08°54'S, 80°41'W.

***Costasignum* new genus**
(Fig. 2B)

Type Species.—*Costasignum macrum* (Menzies and Frankenberg, 1968).

Diagnosis.—Mesosignidae without any lateral extension on pleotelson. Second pereonite much longer than third pereonite. Seventh pereonite with a pronounced lateral extension.

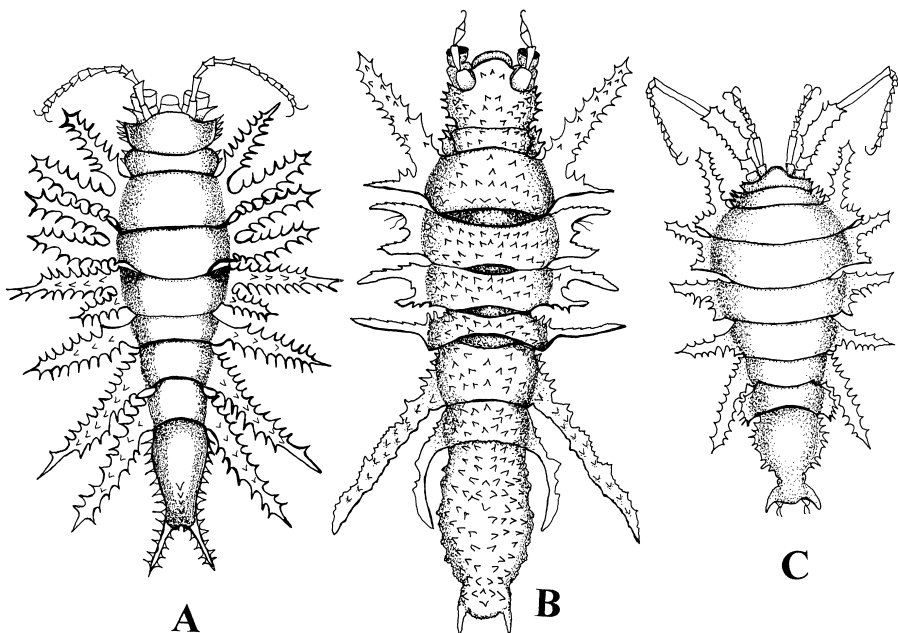


Figure 2. Species belonging to *Costasignum* n. gen. A) *Costasignum vitjazi* (Birstein, 1963) B) Type species *Costasignum macrum* (Menzies and Frankenberg, 1968) C) *Kurilosignum latum* (Birstein, 1970).

Etymology.—The genus name is derived from the nation Costa Rica in Central America and the type was collected from the deep-sea off the coast of Costa Rica.

Remarks.—This genus includes the following two known species:

1. *Costasignum macrum* (Menzies and Frankenberg, 1968) from 3260 m off Costa Rica, Equatorial Pacific at 4°15'N, 86°06'W.

2. *Costasignum vitjazi* (Birstein, 1963) from 6920–7954 m Bougainville trench (New Britain Trench) in the Equatorial Pacific at 05°94.4'S, 152°53.4'E.

***Kurilosignum* new genus**
(Fig. 2C)

Type Species.—*Kurilosignum latum* (Birstein, 1970).

Diagnosis.—Mesosignidae with a pleotelson lacking any lateral extension. Pereonites 2–6 with lateral extensions. Seventh pereonite devoid of a lateral extension. Cephalon reduced and distally broader, not subquadrate. Cephalon not reduced, significantly longer than first pereonite.

Etymology.—The genus has its roots from the Island of Kuril in the northwest Pacific Ocean. The type species was collected from hadal depths in the Kuril-Kamchatka trench.

Remarks.—This genus includes a single species known from the northwest Pacific Ocean, *Kurilosignum latum* (Birstein, 1970) from 5005–6135 m.

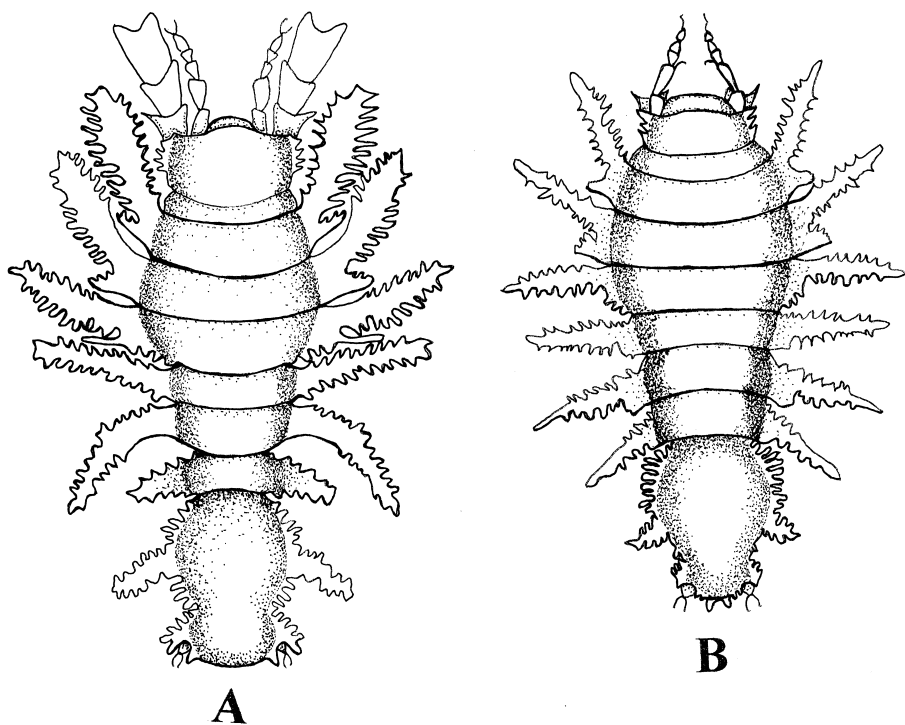


Figure 3. Species belonging to *Japonosignum* n. gen. : A) *Japonosignum brevispinis* (Birstein, 1963) B) Type species *Japonosignum elengatulum* (Birstein, 1963)

***Japonosignum* new genus**
(Figs. 3A,B)

Type Species.—*Japonosignum elengatulum* (Birstein, 1963).

Diagnosis.—Mesosignidae with pronounced lateral spine on pleotelson, in addition to the blunt stout spine-like extension on the posterolateral angles. Pereonites 2–6 with lateral extensions. Seventh pereonite with lateral margin extended. Cephalon well-developed with serrated lateral margin.

Etymology.—The genus name is derived from the nation Japan since the type locality is in the vicinity of Osaka in Japan.

Remarks.—This genus includes the following two known species, both from the deep-sea in the northwest Pacific Ocean.

1. *Japonosignum elengatulum* (Birstein, 1970) from 4000–4150 m, south of Osaka, Japan, 28°53.5'N, 137°21.1'E.

2. *Japonosignum brevispinis* (Birstein, 1963) from 5670 m, southeast of Kurile Islands, 48°50.8'N, 160°01'E.

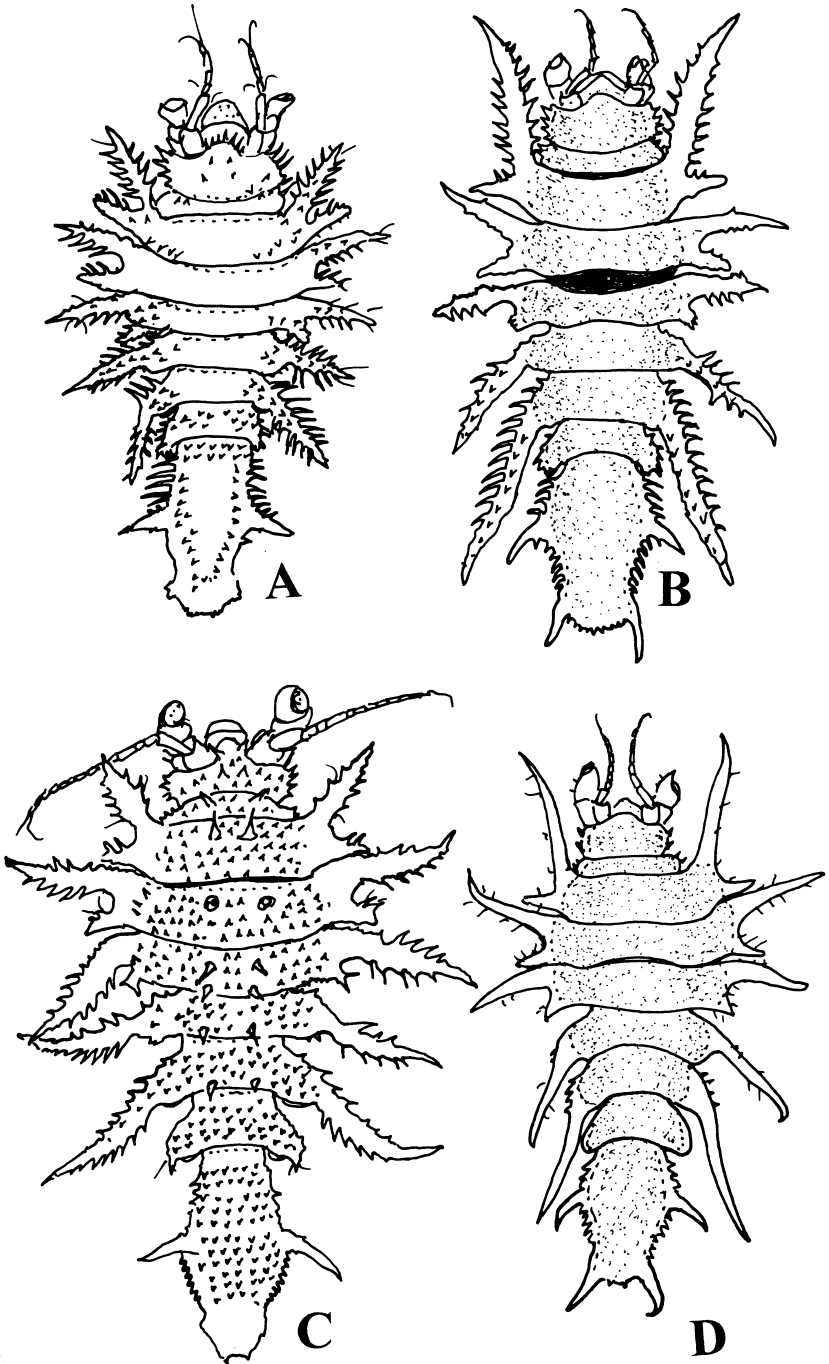


Figure 4. Species belonging to *Bermudasignum* n. gen. : A) *Bermudasignum multidentis* (Menzies and Frankenberg, 1968) B) *Bermudasignum magnadens* (Menzies and Frankenberg, 1968) C) *Bermudasignum admirandum* (Menzies and Frankenberg, 1968). D) *Bermudasignum frankenbergi* n. gen., n. sp. (Type species).

Bermudasignum new genus

(Fig. 4)

Type Species.—*Bermudasignum frankenbergi* n. gen., n. sp.

Diagnosis.—Mesosignidae with pleotelson having large, spine-like lateral extension on either side. Posterolateral angles of pleotelson acute or produced. Seventh pereonite without any lateral extension.

Etymology.—This new genus is named for the Island of Bermuda, in the vicinity of the type locality.

Remarks.—This genus includes three previously known species and a new species described here from the coast of Bermuda in the northwestern Atlantic Ocean. The four species are listed below.

1. *Bermudasignum frankenbergi* n. sp. from 1390–1840 m, off Bermuda, 32°30.9–32°31.0'N, 64°53.5'–64°58.3'W.

2. *Bermudasignum magnadens* (Menzies and Frankenberg, 1968) from 3378 m in the Windward Passage, Caribbean Sea at 20°30'N, 73°16'W.

3. *Bermudasignum admirandum* (Menzies and Frankenberg, 1968) from three localities in the equatorial latitudes: from 1016–1892 m, off Costa Rica in the Equatorial Pacific Ocean at 6°21'N, 85°17'W; from 1363–1369 m off Ecuador at 1°30'S, 82°19'W and 1174–1196 m at the Equator, 00°, 81°45'W.

4. *Bermudasignum multident* (Menzies and Frankenberg, 1968) was collected during three different expeditions off Peru in the Peru-Chile Trench, involving three research vessels, R/V VEMA in 1958, R/V ELTANIN in 1962 and R/V ANTON BRUUN in 1965 (Menzies and George, 1972) from fifteen different localities. These localities are listed in increasing depth from 3372–6354 m: (A) 3372–3493 m at 13°10'S, 56°0.5'W (ELTANIN) (B) 3994 m at 12°03'S, 78°45'W (ANTON BRUUN) (C) 4050 m at 06°08'S, 82°41'W (VEMA) (D) 4506–4555 m at 06°46'S, 82°11'W (ANTON BRUUN) (E) 4661–4723 m at 10°07'S, 80°57'W (VEMA) (F) 4950 m at 06°08'S, 82°41'W (VEMA) (G) 5138–5532 m at 13°18.5'S, 78°03.7'W (ELTANIN) (H) 5490–5666 m at 10°02'S, 80°21'W (VEMA) (I) 5648–5586 m at 09°05'S, 80°43'W (ANTON BRUUN) (J) 5760 m at 07°32'S, 81°26'W (VEMA) (K) 5825–5841 m at 07°35'S, 81°24'W (VEMA) (L) 5986–6134 m at 08°44'S, 80°45'W (ANTON BRUUN) (M) 6073–6281 m at 08°52'S, 80°47'W (ANTON BRUUN) (N) 6146–6354 m at 11°30'S, 79°25'W (ANTON BRUUN) (O) 6324–6238 m at 10°13'S, 80°05'W (VEMA)

KEY TO THE GENERA OF THE FAMILY MESOSIGNIDAE

- 1a. Pleotelson without lateral spine and only with spine or extension at the posterolateral angle ... 2
- 1b. Pleotelson with a pronounced lateral spine or extension, in addition to the spine or extension at the posterolateral angle 4
- 2a. Seventh pereonite lacking any lateral spine or extension 3
- 2b. Seventh pereonite with a prominent lateral spine or extension *Costasignum* n. gen.
- 3a. Cephalon robust and subquadrate *Mesosignum* Menzies, 1962
- 3b. Cephalon reduced and not subquadrate, distally broad *Kurilosignum* n. gen.
- 4a. Seventh pereonite lacking any lateral extension *Bermudasignum* n. gen.
- 4b. Seventh pereonite with a prominent lateral extension *Japanosignum* n. gen.

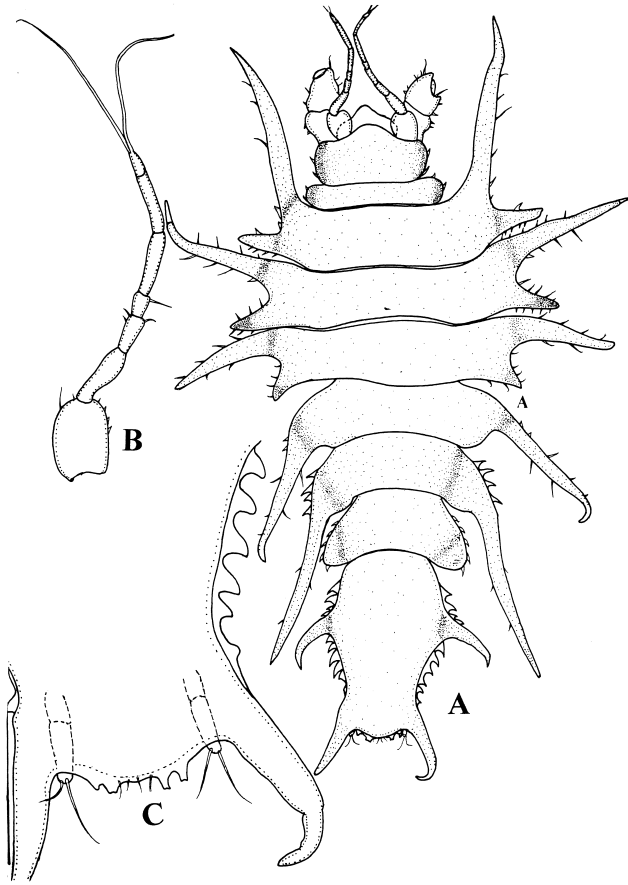


Figure 5. *Bermudasignum frankenbergi* n. gen., n. sp., Holotype female 2.6 mm long, Dorsal View B. Antennule C. Dorsal view of apex of pleotelson, showing the uropods.

***Bermudasignum frankenbergi* new genus, new species**

(Fig. 5)

Diagnosis.—*Bermudasignum* with body devoid of tubercles or setae on the dorsal surface of the body. Cephalon quadrate with two small tubercles on either side of the lateral margin. Large spines on the anterolateral angles of first pereonite reaching to the front, far beyond the second article of antenna. Lateral spine from the sixth pereonite stout and long, reaching backwards beyond one half the length of pleotelson. Pleotelson with lateral spines about as long as the spine-like projection at the posterolateral angles.

Material Examined.—Holotype female, length 2.6 mm, width 1.5 mm. USNM Cat. No.138708.

Type Locality.—R/V EASTWARD Sta. G- 7786, western wall of Bermuda Pedestal, 1390–1840 m, 32°30.9'–32°31.0'N, 64°53.5'–64°58.3'W.

Etymology.—This new species is named in memory of Prof. Dirk Frankenberg, the former director of the Institute for Marine Sciences at Morehead City, University of North

Carolina, who served with me for several years in the University of North Carolina Marine Science Council that established the Duke-UNC Oceanographic Consortium (which provided the ship-time for this study). He was also the co-author of the most extensive paper to date on the isopod genus *Mesosignum*.

Description of the Holotype Female.—General body form with maximum width inclusive of the lateral extensions slightly more than two-thirds the body length. Cephalon robust with two small spines on the lateral margin. First pereonite short, one-third as long as cephalon, without any lateral extensions. Pereonites 2–4 subequal, with anterior lateral projections long and posterior lateral projections short. Anterior lateral projection on second pereonite sword-like, extending forward far beyond the second article of the antenna. All lateral extensions from pereonites with minute and sparsely distributed setae, but no spines. Pereonites 5 and 6 with single long lateral extensions, directed backward.

Lateral projection from sixth pereonite reaching as far as two-thirds the length of pleotelson. Lateral margin of sixth pereonite with four distinct tubercle-like short spines on either side. Seventh pereonite with five small tubercles on lateral margin, lacking lateral extensions. Pleotelson longer than posterior three pereonites combined. Pleotelson with short lateral extensions, which are about as long as the projections from the postero-lateral angles. Lateral margin anterior to the lateral extension with two prominent triangular tubercles and two smaller tubercles. Lateral margin posterior to the lateral extension with six tubercles on either side. Posterior margin of pleotelson with four tubercles.

Antennule is as long as the first three pereonites together. First peduncular article of antennule enlarged and cylindrical, second article narrow and long, fourth article short and about half the length of third article. Fifth and sixth articles narrow and elongated and terminal article short, with two long distal setae. Basal two peduncular articles of antenna broad and robust. Uropod two-jointed and ventrally inserted, tips of uropods barely visible dorsally.

Remarks.—This new species is related to *B. magnadens* from the Windward Passage in the Caribbean Sea with the long spine on second pereonite extending far beyond the second article of second antenna. However, these forward-directed spines in *B. frankenbergi* n. sp. do not have many tubercles on either side as in *B. magnadens*. All lateral spines from pereonites on this new species have just few small setae, but in *B. magnadens* these extensions have a row of short tubercle-like spines. The rounded posterior margin of the pleotelson in this new species has four short spines, but in *B. magnadens* there are seven short spines on the posterior margin of pleotelson.

ORIGIN AND EVOLUTION WITHIN THE FAMILY MESOSIGNIDAE

The family Mesosignidae is one of the 22 families of the superfamily Janiroidea (Wilson, 1987) in the Suborder Asellota of the Order Isopoda. It belongs to the evolutionary branch of Munnoid (*Munna*-like) families that have species mostly in the shallow marine environment. Of the 21 Janiroidean families, 13 families are predominantly deep-sea (e.g., Acanthaspididae, Dendrotonidae, Desmosomatidae, Echinothambematidae, Ianirellidae, Ischnomesidae, Macrostylidae, Mesosignidae, Munnopsidae, Nannoniscidae, Haploniscidae, Pseudomesidae and Thambematidae), despite their emergence to relatively moderate depth in the cold waters of the high latitude environment (George, 2001, 2004). Nine other families (e.g., Antiasidae, Jaeniridae, Joeropsidae, Katinaniridae,

Munnidae, Paramunnidae, Pleurogonidae and Pseudojaniridae) are shallow water families, although some genera have successfully colonized the deep-sea when the cooling events occurred at different geologic periods in the course of climate paleoevolution in the world oceans (Menzies, George and Rowe, 1973, Wilson, 1998, George, 2001). However, the family Mesosignidae is unique since it is exclusively deep-sea, not related to the seven cosmopolitan deep-sea asellote families and more closely related to the *Munna*-like families in shallow water. Furthermore, Mesosignidae is more or less a tropical, deep-sea family (Caribbean and equatorial Pacific and off Bermuda) with no species inhabiting the high latitudes (>58°N or S) in both northern and southern hemispheres.

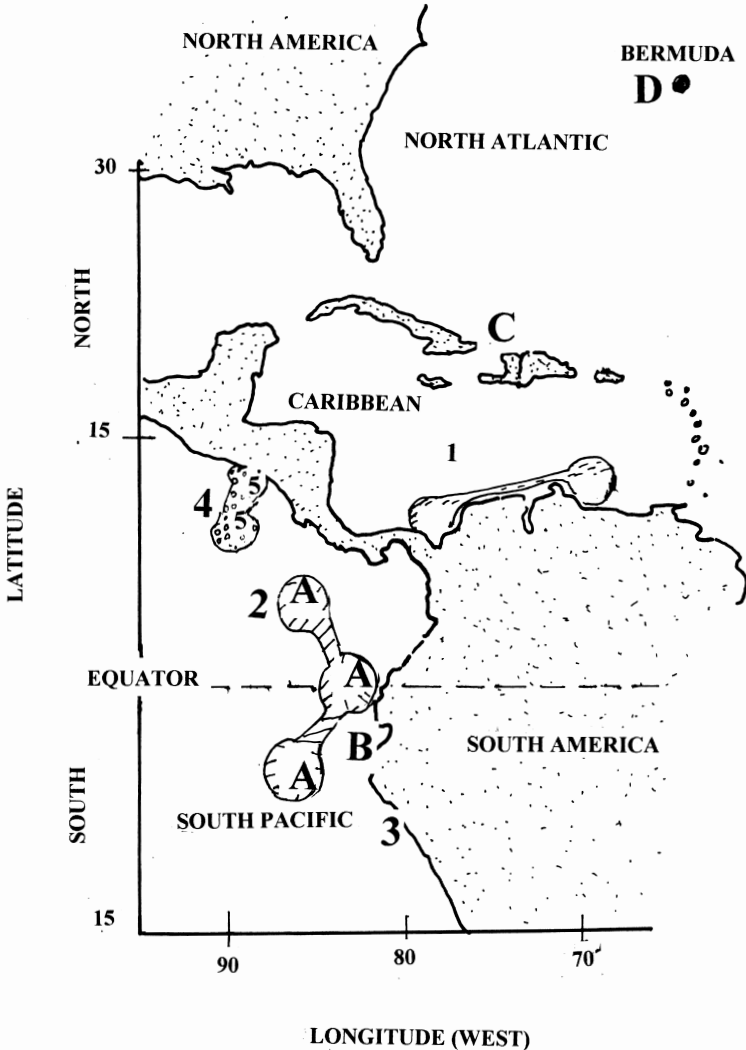


Figure 6. Geographical distribution of species of the Genera *Bermudasignum* and *Mesosignum* of the family Mesosignidae on either side of the Isthmus of Panama, both in the Pacific and Atlantic-Caribbean. I. A) *Bermudasignum admirandum*, B) *Bermudasignum multidentis* C) *Bermudasignum magnadens* and D) *Bermudasignum frankenbergi* n.gen. n. sp. II. 1. *Mesosignum usheri* 2. *Mesosignum kohleri* 3. *Mesosignum truncatum* 5. *Mesosignum ansatum*. 6. *Mesosignum asperum* 7. *Mesosignum* Sp. B

Where did the family Mesosignidae evolve? Why is this family confined mostly to low latitudes? When did the family originate in the deep-sea in geologic time? What climatological or tectonic plate processes influenced the speciation within the family or prevented gene flow between geographically separated populations of same species, particularly after the formation of the Isthmus of Panama that separated the Pacific from the Atlantic-Caribbean? These difficult questions are compounded by poor fossil evidence and our incomplete knowledge about numerous undescribed species. Nevertheless, there is sufficient information to formulate some hypotheses to answer these questions in the future.

When the genus *Mesosignum* was first discovered by Menzies (1962) it was placed as *Incertae Sedis*, not assigned to any known family. Wolff (1962) pointed out the affinity of *Mesosignum* to the following Munna-like genera: *Acanthomunna*, *Antias*, *Dendromunna*, *Dendrotion*, *Hapломunna*, *Kuphomunna*, *Munella*, *Pleurocope* and *Urias*.

Birstein (1963), while describing new species of *Mesosignum* from the north Pacific Ocean, placed the genus under the family Munnidae. Menzies and Frankenberg (1968), while reporting several new species of *Mesosignum* from the tropical latitudes, discussed the similarity of *Mesosignum* with genera within the family Pleurogonidae, both having mandibular molar pointed rather than broad and truncated as in Munnidae. However, Menzies and Frankenberg (1968) also linked *Mesosignum* to *Ianirella* (family Ianirellidae) and to *Schistosoma* (family Schistosomidae) because these genera shared a common feature, the small biarticulate uropods. Genus *Mesosignum* was first assigned to a new family Mesosignidae, established by Menzies and George (1972) when they discovered a new species from the Peru-Chile Trench in the southeast Pacific Ocean.

In this study the systematic status of the family Mesosignidae is carefully reevaluated and five different genera (*Mesosignum*, *Bermudasignum*, *Kurilosignum*, *Costasignum* and *Japanosignum*) are defined within the family Mesosignidae. The distribution of species of the genera *Mesosignum* and *Bermudasignum* is shown in Figure 6. The biogeography of Scleractinian coral species (Cairns, 2000) revealed that the Isthmus of Panama has clearly isolated the east-Pacific fauna from the Atlantic and Caribbean fauna. The genus *Mesosignum* has species on both sides of the Isthmus of Panama in the deep-sea, but not a single species is found on both sides. Is it possible that *M. usheri*, found in several localities in the tropical Pacific, is the ancient species from which other species evolved? The two species of *Mesosignum*, found on the east side of the Isthmus of Panama in the Caribbean off Columbia, *M. kohleri* and *Mesosignum* Sp. A, probably evolved since the formation of the Isthmus of Panama 3.5 million yrs ago.

Mesosignum truncatum, in the Peru-Chile Trench, possibly originated from the parental species *M. usheri* since the formation of the trench in post-Miocene period. It is difficult to explain the origin of *Mesosignum* Sp. B found off Patagonia at 56°S. Two other species found outside the tropical deep-sea are *M. asperum* and *M. ansatum* from the trench depths in the northwest Pacific Ocean. Geologically, trenches were possibly formed after Miocene period about 10 million years ago. Antarctic Bottom Water (ABW) flow has linked the deep-sea of the low latitudes to the these distant trenches as evidenced from speciation in another deep-sea genus *Storothyngura* (George and Menzies, 1968). *Mesosignum ansatum*, and *M. asperum* possibly evolved in situ in the hadal depths of the northwest Pacific Ocean, a similar evolutionary process as the origin of the new genus *Japanosignum* in the deep-sea in the vicinity of Japan.

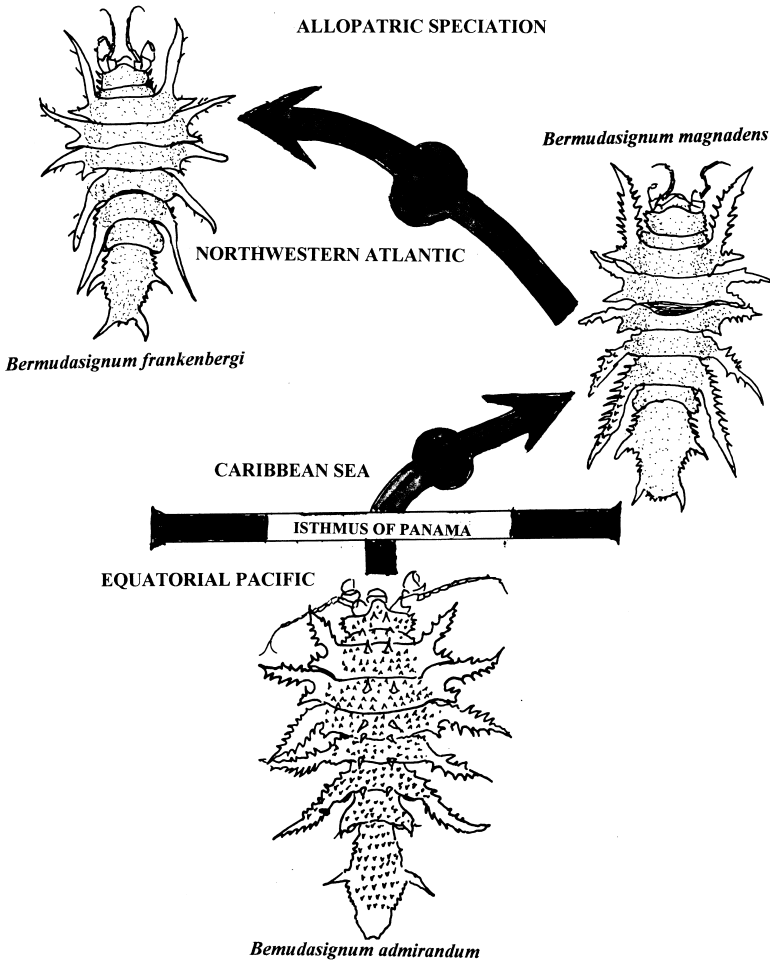


Figure 7. Hypothetical diagram of the origin and evolution of *Bermudasignum frankenbergi* n. gen., n. sp.

The genus *Bermudasignum* contains four known species, two species on either side of the Isthmus of Panama, *B. admirandum* and *B. multidentis* in the southeast Pacific deep-sea and *B. magnadens* and *B. frankenbergi* n. sp. in the Caribbean and northwest Atlantic deep-sea respectively (Fig. 6). A hypothesis is that *B. admirandum* is possibly the most ancestral species from which the other species evolved (Fig. 7).

Perhaps *B. multidentis* originated with the formation of the trench off Peru and subsequently, when the Isthmus of Panama was formed some 3.5 million years ago, the Caribbean deep-sea species *B. magnadens* originated as a consequence of allopatric speciation. Perhaps the most recent evolution event is the speciation of *B. frankenbergi* n. sp. in the vicinity of the island of Bermuda in the northwest Atlantic Ocean.

These hypotheses on the evolution of genera and species within the family Mesosognidae needs to be carefully reaffirmed, or verified by molecular genetic studies of closely related species on the basis of DNA sequencing of selected genes such as the mitochondrial

16 S r RNA in deep-sea amphipod genus *Eurythenes* (France and Kocher, 1996). While discussing the place of origin of deep-sea isopods, Hessler and Thistle (1975) advanced a hypothesis that deep-sea genera evolved in situ on the deep-sea floor and in the course of evolution emerged to shallow depths in the polar and subpolar latitudes. On the contrary, Kussakin (1973) advocated the theory that most deep-sea isopod genera evolved in situ in the Antarctic shelf-slope depths and speciated into the world oceans in the course of evolution since Miocene period. The pattern of speciation, discussed in this study on the deep-sea genera of the family Mesosignidae, does not conform to these two opposing views. George (2001) pointed out that there are different places in the deep-sea for origin of different deep-sea isopod genera, with evidence of site of origin of the genus *Storothyngura* in the Antarctic (George and Menzies, 1968) deep-sea. Nevertheless, the complexity of evolution in the deep-sea calls for further phylogeny and molecular genetic (DNA-sequencing) research, which may elucidate the different mechanisms of speciation and evolution in the abyssal and hadal depths.

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